Nasality and the jazz singer: A review of literature on vocal tract resonance, nasality and formant tuning relating to jazz voice timbre

M5RP1 Assessment 2 – Research Project 1

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INTRODUCTION

It could be said that jazz singers make certain timbral choices in order to produce perceptually instrument-like timbres. My experience as a jazz singer and voice pedagogue has led me to ask whether nasality may be one of these techniques. The purpose of this literature review is to explore what is known as nasality in order to understand its possible contribution to jazz vocal timbre. Physiological context for how the voice functions will be outlined, with a focus on vocal tract resonance, nasality and formant tuning, in order to lay groundwork for future research into how nasality might be used in jazz singing. Studies regarding nasality in singing and methods of formant tuning will be reviewed. Stylistic context relating to the jazz singer and current terminology will be established as correlations are drawn between different fields of thought. Pedagogical literature on jazz voice will also be examined briefly, along with the belief that nasality is not considered advantageous in singing. As no studies of significance have yet been conducted regarding nasality in jazz singing, or the physiological and acoustical events responsible for creating the perception of instrument-like vocal timbres, this literature review will aim to provide necessary groundwork for future studies in this area.

LITERATURE REVIEW

VOCAL TRACT RESONANCE

The human voice is a harmonically rich and complex instrument. As the purpose of this review is to explore vocal tract resonance, nasality and formant tuning relating to jazz vocal timbre, some vital elements of voice production, e.g. respiration and vocal fold activity, will need to be left to the pursuit of fellow researchers. The vocal mechanism is most easily described when separated into three components: *power*, *source* and *filter* (Sundberg, 1987, p. 9; Estill, 2005, p. 5). The focus here will be on the *source* of the sound (vocal fold vibration) and the *filter* that modifies its spectrum (the vocal tract).

A sound source requires a filter or *resonator* to give it energy, power or volume (Fant, 1960; Titze & Story, 1997). A *frequency* is the number of vibrations per second made by a sound source. When a note is sung or played, it comprises a series of frequencies called the *harmonic series*, or individual *harmonics*. The lowest of this series is called the *fundamental frequency* (f_0), which is identified by the human ear as the pitch of the note. The fundamental frequency for speech is typically between 100 to 400 Hz (approx pitches G2-G4), and for singing can be anywhere between 60 Hz and 1500 Hz (approx pitches B1-G6) depending on voice type (Wolfe, Garnier & Smith, 2013).

The *vocal tract* comprises the pharynx and oral cavity, and is formed by the relative positions of the *articulators* – the tongue, jaw, lips, and velum (soft palate) (Sundberg, 1987, p. 93; Story, 2016) *(see Figure 1)*. The articulators move in coordination and are responsible for altering the shape and size of the vocal tract to create the variety of sounds we perceive as vowels and consonants.

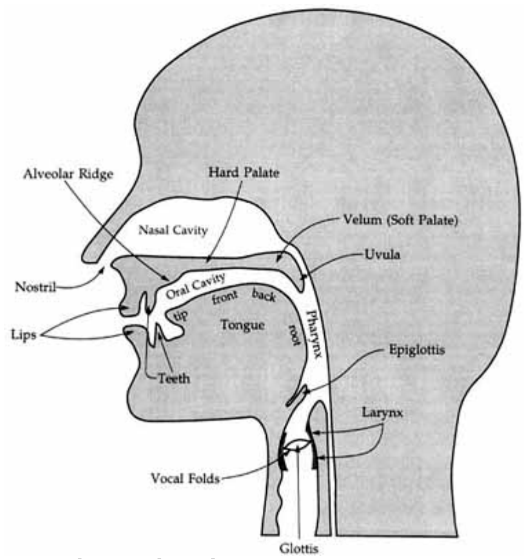

FIG 1. The Vocal Mechanism
Image: http://web.mnstate.edu/houtsli/tesl551/Phonetics/images/vocaltract.jpg

In preparation for speaking and singing, pressurised airflow from the lungs moves towards the larynx and reaches the vocal folds, which are brought together (adducted) by contractions of the laryngeal muscles and the Bernoulli effect, via which a vacuum-effect is created due to changes of air pressure (Sundberg, 1987, p. 13). Sub-glottal air pressure builds due to resistance from the vocal folds, causing the vocal folds to vibrate and release puffs of air (ibid). This rapid vibration translates the air into a sound pressure wave that resonates in the vocal tract, finally exiting the mouth, nose, or both mouth and nose to reach the listener's ear.

The space created by the vocal tract has its own natural frequencies of vibration, called *resonant frequencies* (Sundberg, 1988, p. 12). When a sound wave is introduced into this space, certain harmonics that align with the resonant frequencies of the vocal tract are amplified (strengthened), creating a spectral peak, or *formant* (explained below), while others are dampened (weakened) (Bozeman, 2013, p. 3). This is why the vocal tract is called a *filter*, as it filters out frequencies that don't align with its own resonance. The voice is a unique instrument, as the size and shape of its resonator is continually changing via adjustments of the articulators and larynx height. Conversely, a brass instrument's resonator cannot change size or shape once it has been manufactured. The shape and size of the vocal tract can have a great effect on the listener's perception of *timbre* and their ability to distinguish between different singing styles, e.g. classical, musical theatre, jazz, pop, rock, country (Titze & Story, 1997; Colton & Estill, 1981, p. 399).

Upon hearing a sound, a listener can determine the pitch, loudness and duration of the sound, as well as various environmental characteristics e.g. room reverberation (ibid). All other elements are its *timbre*. Sometimes described as the "colour" of sound (Patil, Pressnitzer, Shamma & Elhilali, 2012, p. 1) or a "multidimensional" quality of sound (Prem & Parncutt, 2008, p. 69), *timbre* can be defined as: (1) one of the primary perceptual vehicles for the recognition and identification of a sound source (e.g. the reason why we can differentiate between a human voice and a saxophone), and (2) a heterogeneous set of sound attributes, some of which are always varying (e.g. brightness, nasality, richness), and others that are discrete or categorical (e.g. the pinched offset of a harpsichord sound) (McAdams & Giordano, 2008, p. 72).

The Italian painting term *chiarascuro* is used in the traditional *bel canto* singing style to describe a desirable balance between 'bright' and 'dark' tones (Stark, 1999, p. 34). In jazz singing, numerous descriptive terms are attached to different vocal timbres – e.g. "powerful", "clear", "nasal", "warm", "authentic" (Prem, Parncutt, Giesriegl & Stigler, 2012). Deeper empirical investigation is needed to determine the physiological events responsible for this diversity of terms.

FORMANTS

The harmonics that fall near the natural resonances of the vocal tract produce associated peaks in the output sound spectrum, or *formants* (F_m) (Fant, 1960; Joliveau, Smith & Wolfe, 2004). The term *formant* has since been used to describe a physical property of the vocal tract (Sundberg, 1988, p. 12), and as yet there is no consistency in terminology across all fields of voice (Titze et al., 2015). For the purposes of this review, the original acoustic definition will be retained. Formants are what determine the perceived timbre – for example, when the upper formants are strong, the sound is perceived as 'bright,' while weak upper formants create a 'mellow', 'quiet' or 'muffled' sound (Wolfe et al., 2013; Wolfe, Garnier & Smith, 2008; Buder, 2005; Styler, 2015; Feng and Castelli, 1996; Chen, 1997).

FORMANT TUNING

As children, we learn to control the acoustic resonances of our vocal tract for everyday speech, intuitively reconfiguring the size and shape of our vocal tracts via the articulators to produce specific formant frequencies for different vowels (Wolfe et al., 2008, p. 6). In singing, this has been developed further to become known as *formant tuning* (Miller & Schutte, 1990; Sundberg, Lã & Gill, 2013), and is considered a vital technique for producing the desired acoustic characteristics of singing (Story, 2016, p. 1; Sundberg, 1987, p. 101). By modifying the vocal tract to boost particular formant frequencies, singers can enhance the sound energy in certain parts of the spectrum either to vary voice quality for stylistic interpretation or to achieve a more efficient production of sound (Wolfe et al., 2008; Sundberg 1987).

A simple way of understanding formant activity is to think of the vocal tract as divided into two containers of air, or resonators (pharynx and oral cavity). The first formant (F_1) is produced by the harmonic interaction that occurs in Container 1 and the second formant (F_2) is produced by the harmonic interaction that occurs in

Container 2 *(See Figure 2)*. Therefore, F_1 is primarily tuned via movement of the jaw and F_2 is primarily tuned via movement of the tongue (Sundberg, 1987, p. 99). However, as the vocal tract functions as an entity, F_2 is also affected by mouth opening (Fant, 1960), therefore the tuning of F_1 can also vary F_2. Although numerous studies have been conducted on formant tuning in classical, musical theatre and even Bulgarian singing styles, it appears that formant tuning in jazz singing is yet to be studied in depth.

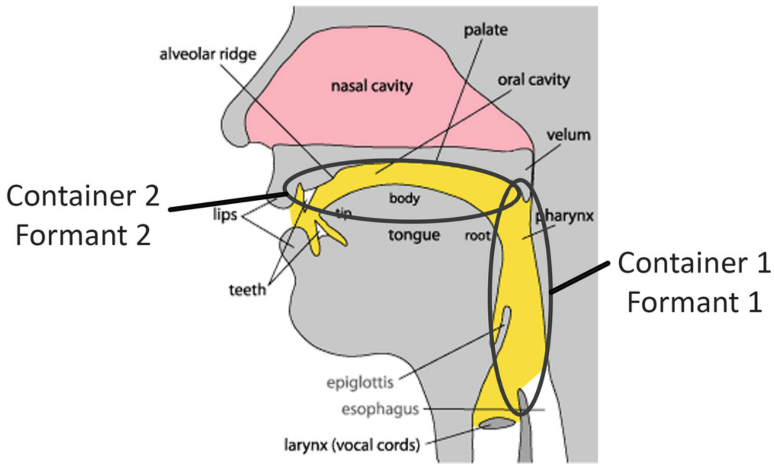

Figure 2. Vocal tract resonators represented as containers of air.
Image courtesy of Mike Gasser/Indiana University:
http://www.voicescienceworks.org/harmonics-vs-formants.html).
Edited by Samantha Walton, 2017.

EPILARYNX TUBE NARROWING ("TWANG")

The *epilarynx tube*, or epilaryngeal tube, is a small portion of space directly above the vocal folds which, when narrowed by a posterior-anterior constriction of the aryepiglottic sphincter, acts as an additional resonator within the vocal tract (Titze & Story, 1997). The role of the epilaryx tube has been likened to that of the mouthpiece of a trumpet – to "shape the flow and influence the mode of vibration" (ibid, p. 2234), and is the defining characteristic of Titze's nonlinear source-filter coupling theory, in which both subglottal and supraglottal reactances can enhance glottal flow.

The acoustic effect of epilarynx tube narrowing is a clustering of upper formants, causing a prominent peak in the spectrum envelope in the 2.8 – 4.3 kHz region (Sundberg, 1988, p. 14). Originally termed the 'singing formant' by Sundberg (1974), this acoustic event has also been referred to as the 'singer's formant', 'squillo' and vocal 'ring' (Titze & Story, 1997, p. 2234), and is the defining characteristic of *twang* (Yanagisawa, Kmucha & Estill, 1990, p. 27). Twang is a voice quality perceptually bright, brassy, or piercing in nature, and has been likened to the quack of a duck or the pluck of a banjo string (Yanagisawa, Estill, Kmucha & Leder, 1989, p. 343). It can be heard in country and western music, however elements of twang are used within all singing styles to some degree, as this voice quality assists *projection*.

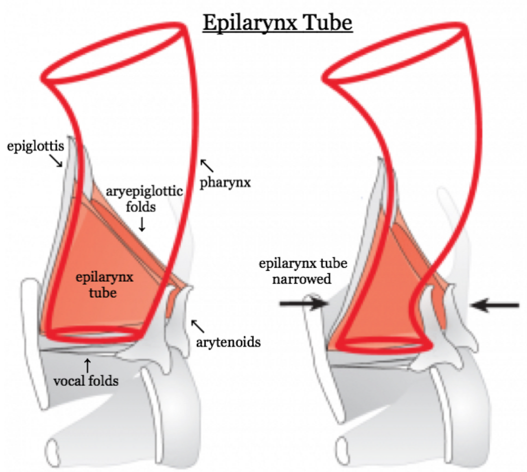

Figure 5. The epilarynx tube sits above the vocal folds and is narrowed via movement of the aryepiglottic sphincter, as in the act of swallowing, causing a boost of harmonics in the 3 kHz region.
Image retrieved from: https://cvtresearch.com/description-of-twang/
Edited: Samantha Walton, Oct 2017

Amplification in the 3 kHz region is perceived as a piercing intensity, as it corresponds with the resonant frequency of the human middle ear. This enables a singer's voice to be heard above an orchestra (of which the loudest frequencies are near 500 Hz) without extra vocal effort (Yanagisawa et al., 1989). In traditional Western classical singing pedagogy, efficiency of voice production was considered vital due to the nature of the acoustic performance environment. Prior to the introduction of the microphone to singing, singers were required to project their voices over large orchestras unamplified, so singers learned to master their control of the upper formants (F_3-F_5) to tune their voice quality without disturbing the overall shaping needed for vowel intelligibility (F_1 & F_2).

Alternative methods of formant tuning in singing have since been documented. As sopranos must often sing pitches where f_0 is much higher than the first formant of the vowel being sung, they have been known to tune F_1 to closely match f_0 (Garnier, Henrich & Wolfe, 2010). Although this strategy of formant tuning sacrifices vowel intelligibility, it allows for resonance efficiency, as the high soprano range enters the spectrum where human hearing sensitivity is greatest (Joliveau et al., 2004) (*See Figure 3)*. It has subsequently been reported that altos and tenors sometimes tune F_1 to the second harmonic ($2f_0$) (Smith, Wolfe, Henrich & Garnier, 2013) – a resonance strategy that can be heard in the traditional folk music of some cultures, e.g. Bulgarian singing (Henrich, Kiek, Smith & Wolfe, 2007). A strong $2f_0$ has also been said to be the defining characteristic of belting – a voice quality used in musical theatre and pop singing (Titze, Worley & Story, 2011, p. 569). It is likely that female jazz singers are employing similar resonance strategies, however a more thorough acoustic analysis is needed in order to draw conclusions.

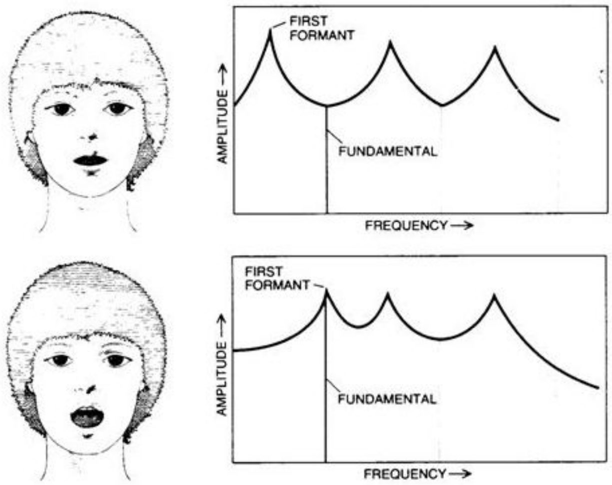

Figure 5.1. The need for a wider jaw opening in the upper range arises from the fact that a soprano must often sing tones whose fundamental (which is actually the lowest partial) is far higher in frequency than is the normal first formant of the vowel being sung. When that is the case, the amplitude of the fundamental is not enhanced by the first formant, and the sound is therefore weak. Opening the jaw wider raises the pitch of the first formant. When the first-formant frequency is raised to match that of the fundamental, the formant enhances the amplitude of the fundamental, and the sound is louder. (From Johan Sundberg, "The Acoustics of the Singing Voice," *Scientific American*, March 1977, Vol. 236, No. 3. By permission.)

Figure 3. F_1 tuning by jaw movement when $F_0 < F_1$.

Some insights into the vocal behaviours of jazz singers are provided in the article *Pedagogy for the Jazz Singer* (Spradling & Binek, 2015). Comparisons are drawn between jazz and classical singing styles via spectrographic analyses, where it is stated that while classical singers register significant resonance activity between F_1-F_6, jazz singers' resonance activity mostly takes place between F_1-F_3 (p. 12). It can therefore be assumed that jazz singers manipulate their vocal tracts in different ways to classical singers in order to achieve distinct vocal timbres. It must be noted, however, that despite the authors' best intentions, the method of spectral analysis used may not have been the most reliable. VoceVista software was used to analyse commercial pre-recorded audio clips of acclaimed jazz singers, therefore harmonic 'noise' created by the accompanying instruments may have distorted the visual information used. In order to obtain more accurate data, isolated recordings need to be created for analysis where study-specific variables are closely monitored.

NASALITY

In order to explore the possible use of nasality as a voice quality in jazz singing, physiological context will now be provided, along with an exploration into existing views on nasality singing. *Nasality* or *nasal resonance* refers to the acoustic coupling of the nasal passages to the oral vocal tract (Titze & Story, 1997; Buder, 2005; Sundberg et al, 2007). When the velum (soft palate) is raised, it closes the passage to the nasal cavity, causing the sound to travel through the mouth only. When lowered, a velopharyngeal opening (VPO) is formed, causing sound to travel through the nose and mouth,

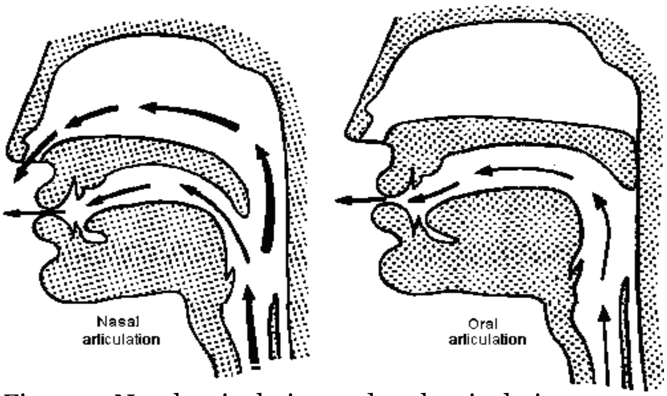

Figure 3. Nasal articulation and oral articulation.
Image courtesy of UNIL website (https://www.unil.ch/sli/fr/home/menuguid/ressources/cours-et-livres-en-ligne/introduction-to-phonetics/introduction.html)

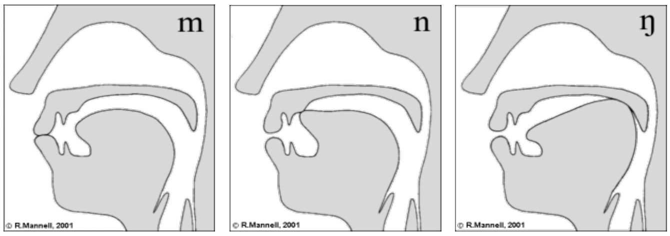

Figure 4. Consonants /m/, /n/ and /ŋ/, all shown with a velopharyngeal opening.
Image courtesy of Mannell, R. (2001)

resulting in partially nasalised vowels (Wolfe et al., 2013) *(See Figure 3)*. When a VPO is combined with constriction of the oral cavity by the lips or tongue, the sound travels through the nasal cavity only. This is a necessary action for producing nasal consonants, of which there are three in the English language (/m/, /n/ and /ŋ/) (Wolfe et al., 2008, p. 11) *(See Figure 4)*.

Acoustically, the nasal cavities have a *damping* (sound absorption) affect on the output sound, as the coupling of the oral and nasal cavities adds *antiresonances* into the spectrum, reducing general amplitude and diminishing upper formant activity (Buder, 2005, p. 4; Yanagisawa, Kmucha & Estill, 1990, p. 27; Wolfe et al., 2013).

The term *hypernasality* is used to describe excessive nasal resonance in the production of oral sounds (Madhu Sudarshan Reddy, Sheela & Kishore Pebbili, 2012; Kummer, 2014), so nasality in vowels is generally considered undesirable in normal speech and resonance in English (Kummer & Lee, 1996, p. 271; LaBouff, 2008, p. 54). This may sometimes be unavoidable, however, e.g. in vowels that precede a nasal consonant (as in 'sing' and 'impossible') (Chen, Slifka & Stevens, 2007), and in some languages, e.g. French, where nasalised vowels are used (e.g. /ã/, /ɛ̃/, /õ/ and /œ/). Another term is *nasalance*, coined by Fletcher (1976), which refers to a specific formula used to measure the amplitude ratio of acoustic energy between the nostrils and mouth. In this review, the term *nasality* will be used when referring to the presence of nasal resonance in vowels during singing.

Despite recent progressions in voice science technology, the status of the VPO during singing remains a topic of contention. Studies have concluded that nasality induces acoustic strength in several regions of the harmonic spectrum (McIver & Miller, 1996) and, contrastingly, that a VPO has little acoustic influence (Titze & Story, 1997). It has been suggested that a degree of VPO may be of assistance in the navigation of the tenor passagio (Birch et al., 2002; Perna, 2008; McCoy, 2008) facilitating a "seamless timbral transition" across registers (Birch et al., 2002, p. 70). Velum control has also been identified as a vocal technique (Estill, 2005, p. 71), via which singers might "fine-tune vocal timbre" (Birch et al, 2002, p. 70).

Historically, nasality has been perceived as a detriment to voice quality in Western classical operatic singing (Tosi, 1743, p. 11; Austin, 1997; McCoy, 2008), where students are taught to avoid nasality entirely to assist projection (McCoy, 2008).

Since the invention of the microphone in 1920 (Gourse, 1997, p. 14), however, approaches to vocal technique have changed dramatically (Lockheart, 2003). Microphones, with the assistance of sound amplification systems, now controlled the acoustic balance between voice and accompanying instruments (Sundberg, 1987, p. 124), making it easier for jazz singers to develop 'natural' timbres and phrasings of a similar nature to their speaking voices (Prem & Parncutt, 2007, p. 348). Singers could experiment with different approaches to vocal tract resonance, no longer restricted by the necessity to project without amplification. This promoted stylistic freedom and broadened the possibilities for artistic expression – ultimately paving the way for the conception of new singing styles (Prem, Parncutt, Giesriegl & Stigler, 2012).

The effect of microphone-use on resonance in the jazz style is highlighted in *Pedagogy for the Jazz Singer* (Spradling & Binek, 2015). Jazz singers are advised to make use of the microphone as a tool for dynamic variety (p. 11), as it effectively acts as an extension of the vocal tract, assisting with resonance and contributing to the final output sound. The authors also propose a raised velum may cause the sound to be "too resonant to remain microphone compatible" (ibid, p. 12), suggesting that too much resonance may cause distortion in the amplification system (ibid, p11). Here the authors appear to be encouraging oral-nasal coupling, possibly to dampen upper formants as a timbral choice, or most likely to avoid sounding too 'classical' when singing in the jazz style.

NASALITY OR TWANG?

Although twang and nasality have clear physiological and acoustic differences, they can occur independently or simultaneously to produce either oral twang or nasal twang (Yanagisawa et al., 1990, p. 27). In fact, twang can often be a useful tool for singers who sing with nasality, as the addition of a 3kHz boost into the spectrum might help to counteract the loss of amplitude caused by nasality. Nasal twang can be heard in some accents, e.g. Australian, and is a possible timbral blend found in jazz singing, however quantitative study is required to support this hypothesis.

A concept that can cause students some confusion is when nasality is mistaken as perceived “brilliance” (Perna, 2008, p. 4). Titze distinguishes between *nasal murmur* (a “honky” quality) and *twang* (a “bright, sometimes ringing” quality) (2001, p. 520), signifying variations in formant activity as earlier described. ‘Nasality’ and ‘twang’ are terms used often by pedagogues to describe particular voice qualities (Estill, 2005; McCoy, 2008), however can sometimes be used interchangeably by students who aren’t provided adequate definitions. Miller, Titze and Austin agree that sympathetic vibrations felt by singers, related to the pedagogical term ‘forward resonance,’ must not be misinterpreted with actual nasal resonance coming from a VPO (Miller, 1993, p. 118; Titze, 2001, p. 520; Austin, 1997, p. 219).

NASALITY IN SINGING

Several studies investigating nasality have been conducted using a variety of methods and equipment (Austin, 1997; McIver & Miller, 1996; Tanner, Roy, Merrill & Power, 2005; Sundberg et al., 2007; Fowler, 2004). These studies primarily focus on the classical singing style, originating from the belief that nasality is detrimental to vocal tract resonance and should be avoided completely (McCoy, 2008). Nasality in jazz singing, however, has seemingly avoided the scientific spotlight – despite the existence of the art form for almost a century (Friedwald, 1990, p. 3). Recently dubbed “America’s classical music” (Bauer, 2007, p. 134), jazz singing has long been in need of empirical investigation to provide a deeper understanding of vocal timbre and vocal techniques including nasality, particularly when singers are producing instrument-like timbres. Following the subsequent outline of studies on nasality in classical singing, hypotheses will be drawn relating to the possible degrees of nasality in jazz singing.

VP closure patterns in classically trained singers were examined by Sundberg et al. (2007) using epoxy models based on CAT scan imaging of a baritone singer’s vocal tract and nasal cavities. Conclusions state that a VPO might be a desirable aspect in classical singing. These findings are similar to a previous study by Birch et al (2002), where a combination of methods were used to record VPO in seventeen classical opera singers. A high correlation was reported between VPO and the production of the vowel /a/, however it was concluded that "a VPO does not necessarily cause a nasal quality," and that due to the subjects' differing shapes of VPO, each singer can "carefully tune the degree of opening, perhaps in order to color the timbre" (p. 70). A subsequent study by Tanner et al. (2005) found classical singers experiencing small amounts of VPO during singing, and recorded significantly higher nasal airflow on the vowel /a/. These results echo an earlier study by Sundberg (2004), where it is proposed that small amounts of VPO, particularly on the /a/ vowel, may dampen F_1 and therefore increase the relative strength of the higher formants in the 3 kHz region. As previously discussed, however, epilarynx tube narrowing may have been responsible for these results.

In a seminal study by Austin (1997), velar movement was measured during speech and singing in professional female classical singers. Results showed there was generally less VPO during singing than speech, and as pitch ascended, VPO reduced. Fowler (2004) also found higher nasalance scores at lower frequencies than higher frequencies, and similar results have been recorded by speech pathologists (Lewis, Watterson & Quint, 2000). As jazz melodies tend to be written for a female's low-to-middle register as opposed to the high range of a classical soprano (Spradling & Binek, 2015, p. 8), it is likely that results found for lower pitches relate to the jazz singer. In jazz singing pedagogy, a more conversational approach to articulation is also advised to avoid sounding 'stilted' or 'stiff,' and singers are encouraged to try speaking the phrases first to gain an understanding of how to approach vowel tuning in the jazz style (ibid, p. 12). This suggests the activity of the articulators in jazz singing may be similar to that found in speech.

Pedagogues Spradling & Binek suggest a degree of VPO is required to achieve a jazz vocal quality (2015; p. 12), however no further definitive analysis is provided. Nasal consonants are also referenced when discussing how to vocalise bass lines and percussion, however it is then stated that the velum should be raised when the consonant combination /dn/ is proposed for a bass drum sound (ibid, p. 15).

Remembering that a VPO is not associated with a raised velum, these instructions create a physiological paradox that requires further clarification.

Based on conclusions from these studies, it is likely a greater degree of VPO may be found in jazz singing than in classical singing, and subsequently a greater possibility of nasality being used as timbral choice within the jazz singing style. Further study is needed to support this hypothesis.

THE JAZZ SINGER

In order to discuss jazz vocal timbre and understand the reasons why a jazz singer's voice may sometimes be perceived as sounding instrument-like, stylistic context will be provided. The umbrella term of "jazz" covers numerous variations of stylistic idioms, however jazz singers are united via one common goal – "a distinctive, highly personal approach to tone" (Bauer, 2007, p. 134). The freedom of timbral expression found in this era of vocal music, enabled by the invention of the microphone as discussed earlier, encouraged singers to develop unique timbres that reflected their individuality (Prem & Parncutt, 2007, p. 348). An understanding of harmony and the jazz idiom was vital for jazz singers, along with advanced ear training to facilitate their improvisational skills (Weir, 2015). In fact, jazz singers such as Ella Fitzgerald, Carmen McRae and Sarah Vaughan are often separated by musicologists from the 'pop' singers of the era, e.g. Frank Sinatra, Tony Bennett, by their ability to improvise (Stephens, 2008, p. 157).

The Bebop Era of the mid to late 1940s transformed the art if jazz improvisation. The word *bebop*, originally a scat syllable (DeVaux, 2000, p. 292), became a defining term to describe a new, revolutionary way of playing jazz. Instrumental soloists performed fast, complex, agile improvisations with unprecedented rhythmic flexibility. This new and exciting world of jazz did not initially cater for vocalists, so when singers such as Dave Lambert joined the instrumental Bebop revolution, the lead melodic role of the voice in the ensemble shifted as arrangements placed voices in horn sections (Friedwald, 1990, p. 226; Martin, 2016). Singers learned to use their voices differently, primarily via imitation, in order to blend with the brass instruments they were singing with. This vocal-instrumental approach found its way into ballads, where singers would opt of a more 'mellow' timbre, e.g. to emulate the sound of a saxophone. Examples of this can be heard in *'My Funny Valentine'* (1954), where Chet Baker's vocal timbre is reminiscent of Gerry Mulligan's baritone saxophone (1953), and *'Moonlight Serenade'* (2001), Kurt Elling's vocalese adaptation of a Charlie Haden bass solo, where horn-like qualities are produced in the opening phrases. It could be said that these singers are using nasality to achieve perceptually instrument-like timbres, however further definitive analysis is required to support this view.

In a perceptual survey (Hargreaves, 2013), forty-two participants perceived that jazz singers use imitation more frequently than instrumentalists when learning music (p. 384). This approach is echoed in an appendix of *Vocal Improvisation* (Weir, 2001), where interviews with critically acclaimed vocal improvisers provide insight into the techniques used for mastering vocal improvisation. Many cited imitation of horn players and transcriptions of horn solos as their primary form of technical development (Lawson, Bridgewater, Clayton, Hendricks, Jordan, Lettau, Shelton & Stoloff, 2001). It is likely these singers are using particular methods of formant tuning to achieve perceptually instrument-like timbres, even if they are unaware of the physiological events occurring within their vocal tracts. During speech, we are most often thinking in terms of the sounds we produce rather than the intentional positioning of our articulators (Sundberg, 1987, p. 96).

Musicologists have likened contemporary jazz singer Esperanza Spalding's voice to the sound a violin (Berlanga-Ryan, 2011) and claimed that Gretchen Parlato's voice "is a cello. It's a muted trumpet, a trombone. It's an alto saxophone" (Greenlee, 2009). Parlato, in particular, uses high degrees of nasality in her singing ('Butterfly', Live in NYC), which could be a result of her Brazilian musical influences where nasality is a distinctive feature. If a nasal vowel is substituted for its oral counterpart in the Brazilian Portuguese language, possibly for the goal of singing with greater acoustic energy, the meaning of the word could change entirely. A recent paper by

Campelo (2017) offers articulatory-acoustic strategies for how Brazilian singers can increase resonance efficiency in the performance of Brazilian art songs. Primarily, it is encouraged that the 'oral phase' of the syllable is elongated in order to maintain vowel formant strength, with the 'nasal phase' articulated as if it were a final consonant to minimise the acoustic effect of nasal coupling (p. 91). This is a strategy intended for classical singers, however, and is derived from the belief that nasality is a detriment to voice quality. On the other hand, nasality is a defining characteristic of the traditional Brazilian vocal quality, and is therefore found in Brazilian-influenced jazz singing (Giddins, 2007).

CONCLUSION

The aim of this literature review was to address the gap in literature regarding nasality in jazz singing and to lay groundwork for future studies in this area. Nasality has been historically perceived as a detriment to voice quality in speech and classical singing, however it is possible it can be used in a musical setting to provide timbral variety. As singers are encouraged to develop unique timbres in the jazz idiom, it could be said that nasality is an important colour in a jazz singer's timbral palette – particularly when endeavouring to produce instrument-like timbres with the voice.

It is this researcher's hypothesis that the methods of formant tuning used by jazz singers differ from the classical 'singer's formant' approach, and may sometimes include nasality for the purposes of producing more instrument-like vocal timbres. To achieve further clarity on this topic, quantitative investigations into methods of formant tuning in jazz singing are required, along with studies into the acoustic effect pitch and vowel placement has on velopharyngeal opening in jazz singing. Qualitative studies could also be conducted regarding the perceptual characteristics of instrument-like voice qualities in jazz singing and their possible links to nasality. Studies of this nature may involve utilising specific timbre descriptors, spectrogram analyses, and other variables. Case studies of jazz singers could also be undertaken, where interviews are conducted in order to determine how jazz singers believe certain timbres are being achieved. A deeper study of the scat vernacular could also provide phonetic context for a more thorough investigation into the links between nasality and perceptually instrument-like voice qualities.

Today we have access to countless pedagogical resources on "how to sing", however most are written specifically for the classical singer and very few focus on the jazz style. This remarkable lack of curiosity about jazz singing by voice pedagogues has led to traditional classical concepts being taught to jazz singers, often resulting in an "overall lack of musical authenticity" (Spradling, 2009, p. 50). Despite the crucial role jazz has played in the development of vocal music, it is only in the past few decades that universities across the globe have developed degree programs in jazz with an emphasis on voice (Spradling & Binek, 2015, p. 10; Weir, 2015). Further empirical investigation is required in order for voice pedagogues and singers to gain a deeper understanding of the physiological and acoustical elements involved in jazz singing,

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